Journal of Forestry Research (2010) 21(1): 93–98
DOI 10.1007/s11676-010-0016-0

RESEARCH PAPER

Soil nematode community structure on the northern slope of Changbai Mountain, Northeast China

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Received: 2009-03-12; Accepted: 2009-06-29

Abstract: Soil nematode communities were investigated in the Changbai Mountain in Broad-leaved Korean Pine forest, Korean Pine and spruce-fix mixed forest, Dark Coniferous forest, Erman's birch forest and Alpine tundra along different altitude gradients from 762 m to 2 200 m a.s.l. Soil animal samples were collected from the litter layer and the soil depth of 0–5 cm, 5–10 cm and 10–20 cm at each site in the spring of 2001 and 2002. In total 27 nematode families and 60 genera were observed. The dominant genera were *Plectus* Bastian and *Tylenchus* Bastian and most of them live in litter layer. The total number of soil nematode was significantly correlated with soil moisture (r=0.357; p<0.01). Nematodes were classified in bacterivores, fungivores, plant parasites, omnivores-predators, and omnivores according to known feeding habitats or stoma and esophageal morphology. Species richness of fungivorous nematode was higher than others in different vegetation communities and soil depths. The total number of soil nematode and trophic groups varied significantly (p<0.05) in response to different soil depths. The fungivore/bacterivore ratio (F/B) and the ratio of (fungivores + bacterivores)/plant-parasites (WI) also changed significantly (p<0.05) in different soil depths. In conclusion, soil moisture is proved to be one of the most important variables affecting nematode density and trophic composition, and the altitude gradient does not significantly affect the ecological indices of soil nematode such as trophic diversity (TD) and the Shannon index (H′).

Keywords: Changbai Mountain; community structure; nematode community

Foundation project: This study was funded by the National Science Foundation of China and project (Grant No.G1999043407) supported by the National Key Basic Research Special Funds (Nos. 30170744 and G1999043407).

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Responsible editor: Hu Yanbo

Introduction

The spatial distribution of a great variety of soil animals in the biosphere plays an important role, not only in determining above- and below-ground primary production and its composition, but also in soil organisms that are known as one of the most sensitive biological markers (Fisher et al. 1987; Whitford 1986). Climatic change is one of the most important environmental problems facing the world today. Since substantial evidence indicated a steady rise in atmospheric CO_2 concentration (Conway et al. 1998), a 3°C increase in global temperature seems inevitable (Hansen et al. 1984). This may result in direct and indirect impacts on the biosphere (Coleman and Bazzaz 1992; Mooney 1991), thus changing the activity, feeding habits and taxonomic diversity of the soil biotic community (Yeates 1987). Any discussion on predicting the direct and indirect response of soil biota to climatic changes is therefore subject to the limitations of climate projections (Steinberger et al. 2000).

One of the most important climatic components affecting soil biota activity in arid and semi-arid systems is moisture availability, which is also one of the main limiting factors for free-living soil nematode activity. Therefore, the moisture availability is particularly well suited for a comparative study along a topoclimatic gradient with emphasis on soil nematode activity, community structure and function, trophic group abundance diversity (Steinberger et al. 1989), colonization and succession in response to disturbances (Bongers 1990; Ettema and Bongers 1993; Yeates 1994).

The present study reports on the abundance and composition of free-living soil nematode fauna in Changbai Mountain, Northeast China, with an objective to provide preliminary information

on nematodes along a climosequence (in this case due to an altitude gradient) in Changbai Mountain.

Study area and methods

Study area

This study was conducted in the Changbai Mountain Reserve of Northeast China, which is a valuable reserve because of its diversity in natural ecosystems and its rich gene pool. This area belongs to a typical temperate zone. The climate changes notably with altitude increments. The average annual temperature is 2.8°C at an altitude of 740 m and changes to –7.3°C at an altitude of 2 623.5 m, characterizing by a sub-alpine climate.

Five study sites were chosen along the altitude gradient on the northern slope of Changbai Mountain, namely: broadleaved-Korean pine (*Pinus koraiensis*) forest, Korean pine and spruce-fir mixed forest, coniferous forest, Erman birch (*Betula ermanii* Cham.) forest, and alpine tundra. According to the report by Wu et al. (2001) the average annual precipitation in this area increased with altitude from 691.40 mm at 762 m to 1 154.34 mm at 2 200 m. The mean annual temperature also varied from 2.58°C to –4.84°C over this gradient (Table 1).

Table 1. Geographic and climatic data for five sites along an altitude gradient on the northern slope of Changbai Mountains, China

Study site	Elevation (m)	Latitude and longitude	Average annual rainfall (mm)	Average annual temperature (°C)
1.Broadleaved-Korean pine (*Pinus koraiensis*) forest	762	42º24′05′′ N−128º05′43′′ E	691.40	2.58
2.Korean pine and spruce-fir mixed forest	1219	42º08′02′′ N 128º07′44′′ E	810.53	0.27
3.Coniferous forest	1659	42º04′14′′ N 128º03′41′′ E	967.28	-2.29
4.Erman birch (*Betula ermanii* Cham.) forest	1900	42º03′38′′ N 128º04′04′′ E	1038.16	-3.31
5.Alpine tundra	2200	42º02′27′′ N 128º04′08′′ E	1154.34	-4.84

Methods

Four 100-m^2 sites were selected for every age-rank. Soil animal samples were collected from the litter layer and the soil depth of 0–5 cm, 5–10 cm and 10–20 cm at each site in the spring of 2001 and 2002. A total 600 samples were collected in two years. The samples were placed in plastic bags and transported to the laboratory in a cooler.

A minimum of 3 g of soil from each sample at each site was weighed and dried at 105°C for gravimetric determination of the soil water content. An additional 100 g dry soil of each replicate was taken for nematode extraction. The nematode extraction was conducted using the centrifugal flotation method. Soil animal was identified by microscope. The genus was identified as usual according to pictrorical keys to soil animals of China (Yin 2000) and the individual number was collected by statistics.

Nematodes from each sample were collected and identified according to order, family and genus, using a compound microscope. Nematodes were classified in the following trophic groups: bacterivores, fungivores, plant parasites, omnivores-predators, and omnivores according to known feeding habitats or stoma and esophageal morphology (Steinberger and Sarig 1993; Yeates et al. 1993).

The nematode community was analyzed using the following approaches:

The absolute abundance of individuals in 100 g dry soil.

The absolute number of nematodes in each trophic structure.

Several ecological indices: a fungivore/bacterivore ratio (F/B) (Twinn 1974), WI, which is the ratio of (fungivores + bacterivores)/plant-parasites (Wasilewska 1994), trophic diversity (TD), $TD = 1/\Sigma P_i^2$ (Heip et al. 1988), Simpson's diversity (SI), $SI=1-\Sigma P_i^2$ (Freckman and Ettema 1993), and the Shannon index (H′), $H' = -\Sigma P_i(\ln P_i)$ (Freckman and Ettema 1993).Where *Pi* is proportion of plant-parasitical nematode community individual in the kind of *i* account for total number.

All analyses were based on the relative abundance of nematode families. Analysis of variance (ANOVA) was performed on the data using a statistical analysis system (SPSS12.0) set. ANOVA analysis is very significant when $p<0.05$.

Results

The average soil moisture content ranged from a maximum of 0.625% in the 0–5 cm of the alpine tundra to a minimum of 0.150% in the 10–20 cm of the coniferous forest soil (Fig. 1). A significant difference in soil moisture content was found between the depths ($p<0.01$) and between the locations ($p<0.01$) (Table 2): 0–5 cm > litter layer> 5–10 cm > 10–20 cm, alpine tundra > coniferous forest > broadleaved-Korean pine forest > Erman birch forest > Korean pine and spruce-fir mixed forest (Fig. 1).

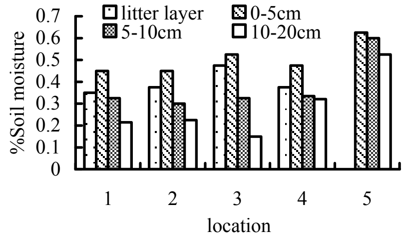

Fig. 1 Soil moisture across the four depths at the five locations (1. Broadleaved-Korean pine (*Pinus koraiensis*) forest, 2. Korean pine and spruce-fir mixed forest, 3. Coniferous forest, 4. Erman birch (*Betula ermanii* Cham.) forest, 5. Alpine tundra)

Table 2. Univariate analysis of variance (ANOVA) for soil moisture, total free-living soil nematodes and ecological indices across four depths at five locations on the northern slope of Changbai Mountains, China during the spring of 2001 and 2002

Index	Depth *F*-test	*p*value[c)]	Location *F*-test	*p*value
Soil moisture	4.84	0.004	6.94	0.000
Soil nematodes	22.05	0.000	2.46	NS
Trophic structures[a)]				
BF	16.04	0.000	2.33	NS
FF	3.65	0.016	3.00	0.024
PP	13.20	0.000	5.12	0.001
OP	9.95	0.000	2.33	NS
OM	12.43	0.000	1.09	NS
Ecological indices[b)]				
F/B	2.96	0.038	2.71	0.037
WI	2.91	0.040	3.47	0.012
TD	1.19	NS	2.40	NS
SI	1.72	NS	2.52	0.049
H′	1.89	NS	1.60	NS

[a)]Trophic structures: BF, bacterivores; FF, fungivores; PP, plant-parasites; OP, omnivores-predators; OM, omnivores (absolute numbers); [b)]Ecological indices: F/B, ratio of fungivores to bacterivores; WI, ratio of bacterivores plus fungivores to plant-parasites; TD, trophic diversity index; SI, Simpson's index; *H′*, Shannon index; [c)]NS, not significant (p>0.05)

A total 27 nematode families and 60 genera were found in the nematode suspensions, and the dominant genera were *Plectus* Bastian and *Tylenchus* Bastian. The maximum mean relative abundance of *Plectus* was found in the vegetation litter layer of the coniferous forest. The percentage of *Plectus* across the soil depths exhibited similar trends in the Korean pine and spruce-fir mixed forest, coniferous forest, Erman birch forest, and the alpine tundra, with number order in different depths of soil: the litter layer > 0–5 cm > 5–10 cm > 10–20 cm. The mean relative abundance of *Tylenchus* across the four soil depths also exhibited this pattern in the coniferous forest, the Erman birch forest and the alpine tundra.

The total number of nematodes during the study period ranged from 11 to 4 727 individuals in 100 g^{-1} dry soil. Significant differences in total number of nematodes were found between depths (p<0.01) (Table 2) with the litter layer > 0–5 cm > 5–10 cm > 10–20 cm (Fig. 2). A correlation was found between the total number of nematodes and moisture content (r=0.357, p<0.01).

The maximum mean population density in 100 g^{-1} dry soil of the litter layer was 2 456, 114, 1 317, 1 286 and 416 individuals for bacterivores, fungivores, plant parasites, omnivores-predators and omnivores, respectively, as shown in Fig. 3. Bacterivores (BF) was the most abundant group in the litter layer in Changbai Mountain area (Fig. 3). Significant differences between the five trophic groups were found between depths of soil (p < 0.01) (Table 2).

Figure 4 presented the changes in the F/B ratio across the four depths in the five types of forests. The maximum mean F/B ratio was found in the 5–10 cm soil layer of the Korean pine and spruce-fir mixed forest, with the minimum found in both the 0–5 cm layer of the broadleaved-Korean pine forest and the litter of the Erman birch forest. Significant differences were found between depths (p<0.05) and locations (p<0.05).

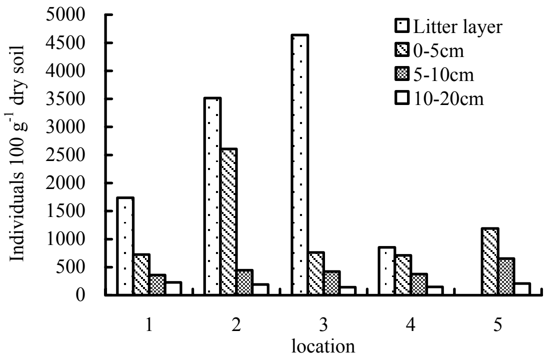

Fig. 2 Total number of nematodes across the four depths at the five locations (1. Broadleaved-Korean pine (*Pinus koraiensis*) forest, 2. Korean pine and spruce-fir mixed forest, 3. Coniferous forest, 4. Erman birch (*Betula ermanii* Cham.) forest, 5. Alpine tund).

WI in the coniferous forest fluctuated greatly across the four depths (Fig. 4). The maximum and minimum mean WI values were found in the litter layer of the coniferous forest and at 5–10 cm of soil depth, respectively, in the Korean pine and spruce-fir mixed forest. There were differences between depths (p<0.05) and between locations (p<0.05).

Maximum and minimum mean TD ratios were found at 5–10 cm depth of soil in the coniferous forest and the litter layer of the Erman birch forest, respectively. However, no significant differences (Table 2) were found between soil depths and between locations. The mean values of SI (Fig. 4) fluctuated greatly across the five locations, but there were no significant differences (p<0.05) among depths (see Table 2). The Shannon index (*H′*) also fluctuated slightly across the four depths at the five locations (Fig. 4); however, no significant differences were found between soil depths and between locations (see Table 2).

Discussion

Soil moisture content at the five sites increased dramatically along the elevation gradient of Changbai Mountain. The increase in soil moisture content observed in the alpine tundra may be due to rainfall formation. According to Steinberger et al. (2000), rainfall increased with the increment of altitude.

In the present study, 60 soil nematode genera were detected, of which more than 44 genera were reported by Yin (2000) in the Changbai Mountain area, in the broadleaved-Korean pine mixed forest. Similarly, the mean population density of nematodes (1 027 individuals in 100 g-1 dry soil) across the five locations was comparable to that reported by Yin (2001) for the Liangshui National Nature Reserve region of Xiaoxing'an Mountain in northeast China.

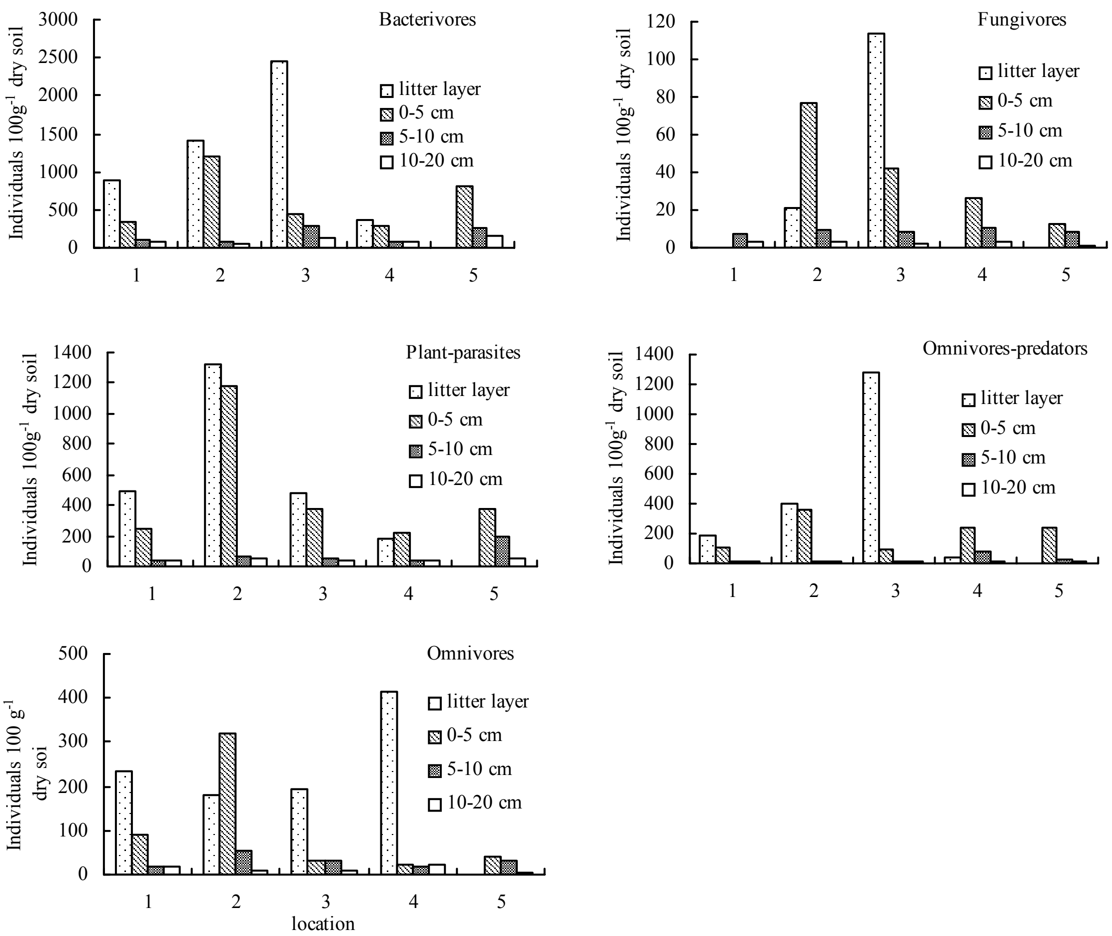

Fig. 3 Changes in nematode trophic groups across four depths and at five locations on the northern slope of the Changbai Mountains, China during the spring of 2001 and 2002) 1. Broadleaved-Korean pine (*Pinus koraiensis*) forest, 2. Korean pine and spruce-fir mixed forest, 3. Coniferous forest, 4. Erman birch (*Betula ermanii* Cham.) forest, 5. Alpine tund.

The F/B ratio is known to be an important indicator of the decomposition pathway in a detritus food web (Sohlenius and Sandor 1987). The F/B ratio in this study (0.05) was lower than that estimated for meadow sites (0.45) by Wasilewska (1994). The increased proportion of bacterivore nematodes means that there is a high ratio of bacterial community in the soil decomposer system. The organic material would decompose more rapidly if the decomposed dominant nematode by bacteria (Porazinka and Coleman 1995), because the decomposition rate of the bacteria-based food web is rapider than fungal-based food web. F/B reflects the structure of soil microbial communities (Liliana 2003). All samples' F/B values in this study were less than 0.45, indicating that the litter is mainly decomposed by the bacteria.

The mean value of WI in our investigation was 1.65, which is comparable to the range (1.60–8.70) of mean values observed by Wasilewska (1994) for meadows in northeast Poland. The WI index reflects the structure of nematode populations and the soil health. When WI = 1 shows that the beneficial non-plant parasitic nematodes has as the same as quantity of harmful plant parasitic nematodes, and the soil is common healthy. The soil is healthier with bigger value of WI when WI>1. Whereas WI <1, it means the poorer health status of soil. Our study result of WI 1.65 means the soil is healthy.

The TD value of 2.72 found in the present study was lower than those found in cropping systems (2.94–3.14) obtained by Freckman and Ettema (1993), which indicates there is difference between the two systems. Nutritional diversity can reflect how the feeding diversity of nematode changes. Nutrition diversity increase is usually correlated with the increase in frequency of fungivore nematodes and predatory nematodes/omnivorous nematodes. The lower nutritional diversity measured in this study in forest ecosystems means the forest ecosystem may be affected by human interference.

The mean SI of 7.51 in this study was significantly higher than the mean value (6.73) obtained by Freckman and Ettema (1993). The Shannon Index (H') gives more weight to rare species, and a higher index indicates greater diversity. The mean H' value of 2.22 in the Changbai Mountain experimental plots is higher than that observed for agroecosystems by Wasilewska (1994) and lower than that found in a rain shadow desert by Steinberger et al.

(2001).

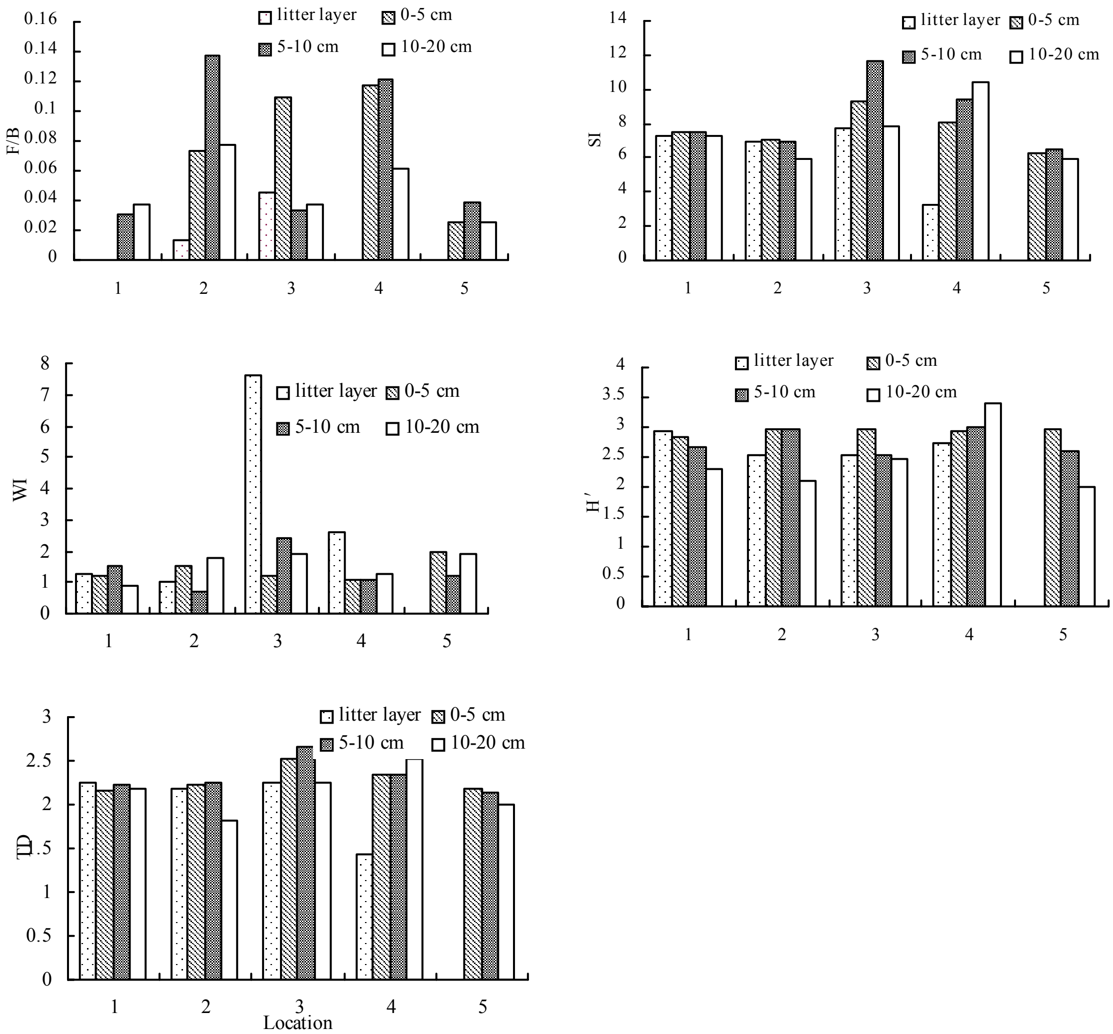

Fig. 4 Variation in ecological indices for soil nematodes across four depths and at five locations on the northern slope of the Changbai Mountains, China during the spring of 2001 and 2002). 1. Broadleaved-Korean pine (*Pinus koraiensis*) forest, 2. Korean pine and spruce-fir mixed forest, 3. Coniferous forest, 4. Erman birch (*Betula ermanii* Cham.) forest, 5.Alpine tund

In conclusion, the differences between data obtained in this research and studies conducted at different sites for different systems indicate that the most important feature differentiating the locations is soil moisture, which is clearly one of the most important variables affecting nematode density and trophic composition. Additionally, the altitude gradient did not significantly affect such ecological indices as TD and *H′* for soil nematodes.

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